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Development and validation of a questionnaire to assess pedestrian receptivity toward fully autonomous vehicles

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ABSTRACT

This study analyzes pedestrian receptivity toward fully autonomous vehicles (FAVs) by developing and validating a pedestrian receptivity questionnaire for FAVs (PRQF). The questionnaire included sixteen survey items based on attitude, social norms, trust, compatibility, and system effectiveness. 482 Participants from the United States (273 males and 209 females, age range: 18–71 years) responded to an online survey. A principal component analysis determined three subscales describing pedestrians' receptivity toward FAVs: safety, interaction, and compatibility. This factor structure was verified by a confirmatory factor analysis and reliability of each subscale was confirmed (0.7 < Cronbach's alpha < 0.9). Regression analyses investigated associations with scenario-based responses to the three PRQF subscale scores. Pedestrians' intention to cross the road in front of FAVs was significantly predicted by both safety and interaction scores, but not by the compatibility score. Accepting FAVs in the existing traffic system was predicted by all three subscale scores. Demographic influence on the receptivity revealed that males and younger respondents were more receptive toward FAVs. Similarly, those from urban areas and people with higher personal innovativeness showed higher receptivity. Finally, a significant effect of pedestrian behavior (as measured by the pedestrian behavior questionnaire) on receptivity is explored. People who show positive behavior believed that the addition of FAVs will improve overall traffic safety. Those who show higher violation, lapse and aggression scores, were found to feel more confident about crossing the road in front of a FAV. This questionnaire can be a potential research tool for designing and improving FAVs for road-users outside the vehicles.

1. Introduction

The highest percentage increase in traffic deaths within one year in the United States occurred in 2015 (National Safety Council, 2016), the most recent year for which statistics are available. Among the fatalities in that year, the number of pedestrian fatalities was 5376, a 9.5% increase from 4910 pedestrian fatalities in 2014 (National Center for Statistics and Analysis, 2017). The Governors Highway Safety Association predicted an 11% increase in pedestrian fatalities on U.S. roadways,

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compared to 2015 (Retting and Schwartz, 2017). *The National Motor Vehicle Crash Causation Survey* (NMVCCS), conducted from 2005 to 2007, reported that around 94% of traffic crashes are at least partially a result of human error (Singh, 2015). In the case of pedestrian-related traffic crashes, the driver, the pedestrian, or both may be the guilty party. Pedestrians are vulnerable road-users and previous report have stated that a large percentage pedestrians (around 60%) do not trust that vehicles (drivers) will respond appropriately toward them (Karsch et al., 2012). However, pedestrians can themselves be spontaneous road-users and make risky decisions in assessing the danger that vehicles pose. Pedestrians can also allow themselves to be distracted with cell phones, music, a companion, or any number of other daily distractions while interacting with traffic. Although this can be true of other road-users as well, pedestrians are one of the most vulnerable and face the greatest danger should they miscalculate a risk. To address these issues with human error made both by drivers and pedestrians as well as to enhance overall traffic safety and improve user convenience (older adults, users with medical conditions that limits driving), recent research has been focusing on transferring vehicle control from human drivers to automated systems with the ultimate goal of developing fully autonomous vehicles (FAVs).

The current research on the semi and/or fully autonomous vehicles and the subsequent innovation of emerging automotive technologies indicate a potential for improved traffic safety along with expanded mobility. Automated vehicle technologies are designed to be able to sense and make judgments about the external environment (e.g. road signs, other road-users, traffic density) and actions the vehicle should take. However, these judgments are dependent on the proper functioning of all cameras, lasers, sensors, and radar scanners that comprise the technology. FAV, an advanced invention within automated vehicle technologies, is still in the research-and-development phase with numerous ongoing experiments; studies seek to improve this technology by addressing all the risks associated with it. For example, the detection of other vehicles and road users (bicyclists, motorcyclists, and pedestrians) (Häne et al., 2015; Litman, 2015; Levinson et al., 2011) and the design of external interfaces to interact with these vehicles (Vissers et al., 2016; Peters, 2017; Deb et al., 2016). Merat and Lee (2012) investigated driver interaction with autonomous vehicles and revealed that automation cannot substitute flawlessly for a human driver, nor the driver can safely accommodate the limitations of automation. Therefore, it is necessary to research on the perspective of the vulnerable road users (pedestrians, cyclists, people in wheel-chairs), toward an unfamiliar technology and unknown dynamic.

The process of introducing a new technology is not always smooth. Many significant innovations fail to satisfy user requirements and get abandoned before their launch into the market (Story et al., 2011). The main obstacles in achieving a place in the market include not only technological issues, but also the lack of acceptance toward new ideas (Vahidi and Eskandarian, 2003). Many researchers have studied acceptance of advanced vehicle technologies from the user or buyer perspectives (Harper et al., 2016; Bansal et al., 2016; Nordhoff et al., 2016; Kyriakidis et al., 2015; Underwood, 2014; Wallace and Silberg, 2012). The current research is focused on pedestrian receptivity to advanced vehicle technology and has found it important to understand this receptivity so that pedestrian perspectives can also be considered with technology improvements.

2. Background

2.1. Human factors research on autonomous vehicles

In an autonomous vehicle, various functions are controlled by software and hardware allowing those functions to operate independent of a driver. This technology can reduce physical and mental stress for drivers, as well as increase safety for all road-users and reduce fuel consumption (Mersky and Samaras, 2016; Keen, 2013). Based on the levels of automation proposed by Parasuraman et al. (2000), SAE International (SAE) divides vehicle automation into six levels (National Highway Traffic Safety Administration, 2016):

- SAE Level 0 (No automation): human driver is at the control of the driving task even when equipped with warning and/or intervention systems;
- SAE Level 1 (Driver assistance): human driver performs all aspects of the dynamic driving task when automated system can assist the driver with one driver assistance system of either steering or acceleration/deceleration;
- SAE Level 2 (Partial automation): human driver performs all aspects of the dynamic driving task when automated system can assist the driver with one or more driver assistance systems of both steering and acceleration/deceleration;
- SAE Level 3 (Conditional automation): automated driving system performs all aspects of driving mode-specific performance; however, the human driver must be ready to take back control to a request to intervene;
- SAE Level 4 (High automation): automated driving system performs all aspects of driving tasks, even if a human driver does not need to take back control to a request to intervene. However, the automated system can operate only in certain environments and under certain conditions;
- SAE Level 5 (Full automation): the automated system performs all driving tasks, in any environment and under all conditions that can be conducted by a human driver.

A Fully Autonomous Vehicle (FAV) is categorized as a level 5, a vehicle automation technology that takes full control of the vehicle to execute all safety-critical driving tasks for an entire trip. At this level of automation, the vehicle can be